Status of $h \to \mu^+\mu^-$ Analysis

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2020/February/26

ILD Analysis/Software Meeting

General Status

- Working on DBD-paper for final editing
- Last talk: 2019/Sep./3 (monthly ILD group meeting)

- Found a problem in smearing of p_T resolution (see Jenny's slide on Feb./12)

Smearing

- Study of the impact of transverse momentum resolution σ_{1/p_T}
- Assume some number on σ_{1/p_T}, make a random number using gRandom function, then create smearing vector and add it to 4-momentum (MC truth)

- Problem: smearing vector was $(\sigma_{px} \quad \sigma_{py} \quad 0 \quad 0)$, not $(\sigma_{px} \quad \sigma_{py} \quad \sigma_{pz} \quad \sigma_E)$, because I thought that only considering x and y components are enough.

Previous: Only x&y Components Considered

$$\sigma^2\left(M_{\mu^+\mu^-}\right) = \frac{1}{M^2_{\mu^+\mu^-}}\left[P_1^T \Sigma_2 P_1 + P_2^T \Sigma_1 P_2\right]$$

$$P_i = \begin{pmatrix} E_i \\ p_{ix} \\ p_{iy} \\ p_{iz} \end{pmatrix}, P_i^T = \begin{pmatrix} E_i & -p_{ix} & -p_{iy} & -p_{iz} \end{pmatrix},$$

$$\Sigma_i = \begin{pmatrix} \sigma^2_{E_i} & \sigma_{E_i p_{ix}} & \sigma_{E_i p_{iy}} & \sigma_{E_i p_{iz}} \\ \sigma_{p_{ix} E_i} & \sigma^2_{p_{ix}} & \sigma_{p_{ix} p_{iy}} & \sigma_{p_{ix} p_{iz}} \\ \sigma_{p_{iy} E_i} & \sigma_{p_{iy} p_{ix}} & \sigma^2_{p_{iy}} & \sigma_{p_{iy} p_{iz}} \\ \sigma_{p_{iz} E_i} & \sigma_{p_{iz} p_{ix}} & \sigma_{p_{iz} p_{iy}} & \sigma^2_{p_{iz}} \end{pmatrix}$$

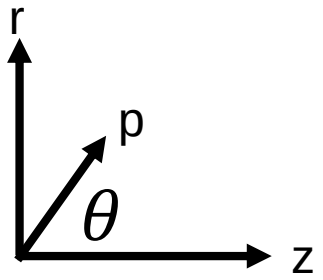
$$\sigma_{p_T} = p_T^2 \cdot \sigma_{1/p_T}$$

$$\sigma_{p_x} = p_T^2 \cdot \sigma_{1/p_T} \cdot \cos\phi$$

$$\sigma_{p_y} = p_T^2 \cdot \sigma_{1/p_T} \cdot \sin\phi$$

$$\sigma_{p_z} = \frac{\sigma_{p_T}}{\tan\theta} = \frac{p_T^2 \cdot \sigma_{1/p_T}}{\tan\theta}$$

$$\sigma_E = \sigma_p = \frac{\sigma_{p_T}}{\sin\theta} = \frac{p_T^2 \cdot \sigma_{1/p_T}}{\sin\theta}$$



Solution: Mass Using Polar Coordinates

When we assume muons are massless, the invariant mass of muon pairs M can be written as;

$$M^2 = 2p_1p_2(1 - \cos\alpha),$$

do some mathematics and implement track parameter relations;

$$\begin{aligned} M^2 &= 2p_{T1}p_{T2}\left(\frac{1}{\sin\theta_1\sin\theta_2} - \cos\phi_1\cos\phi_2 - \sin\phi_1\sin\phi_2 - \frac{1}{\tan\theta_1\tan\theta_2}\right) \\ &\equiv 2p_{T1}p_{T2}\cdot\mathrm{coeff} \\ \therefore M &= \sqrt{2p_{T1}p_{T2}\cdot\mathrm{coeff}}. \end{aligned}$$

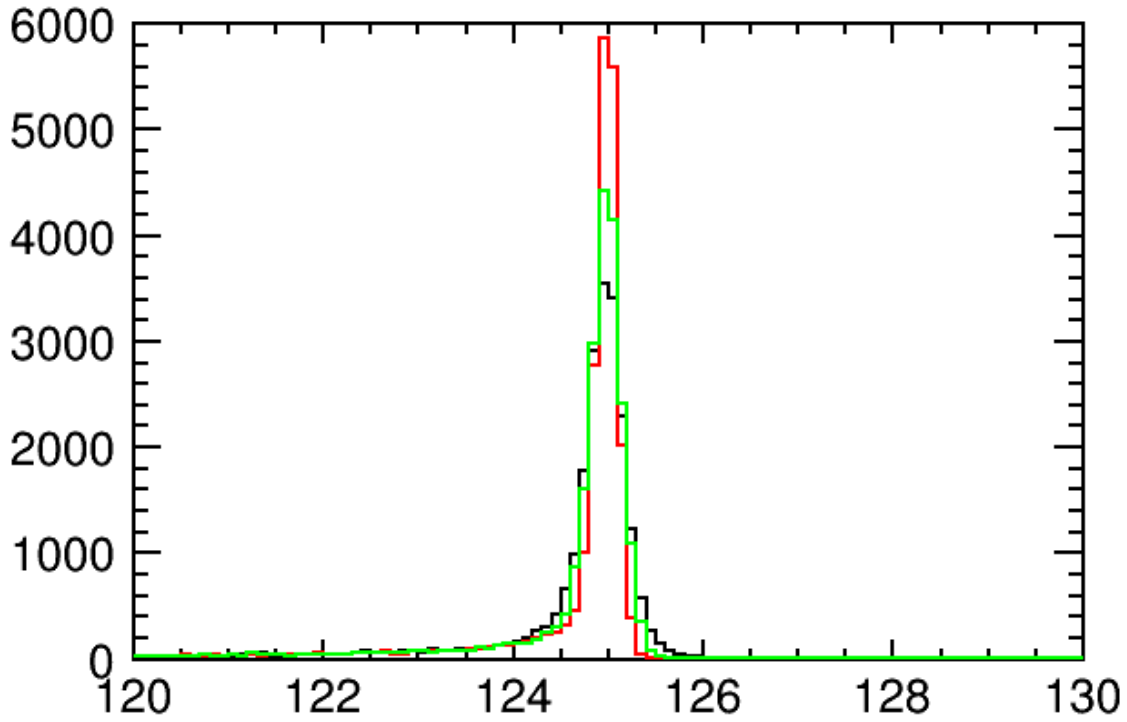
only contains polar/azimutial angle

More Healthy Smearing

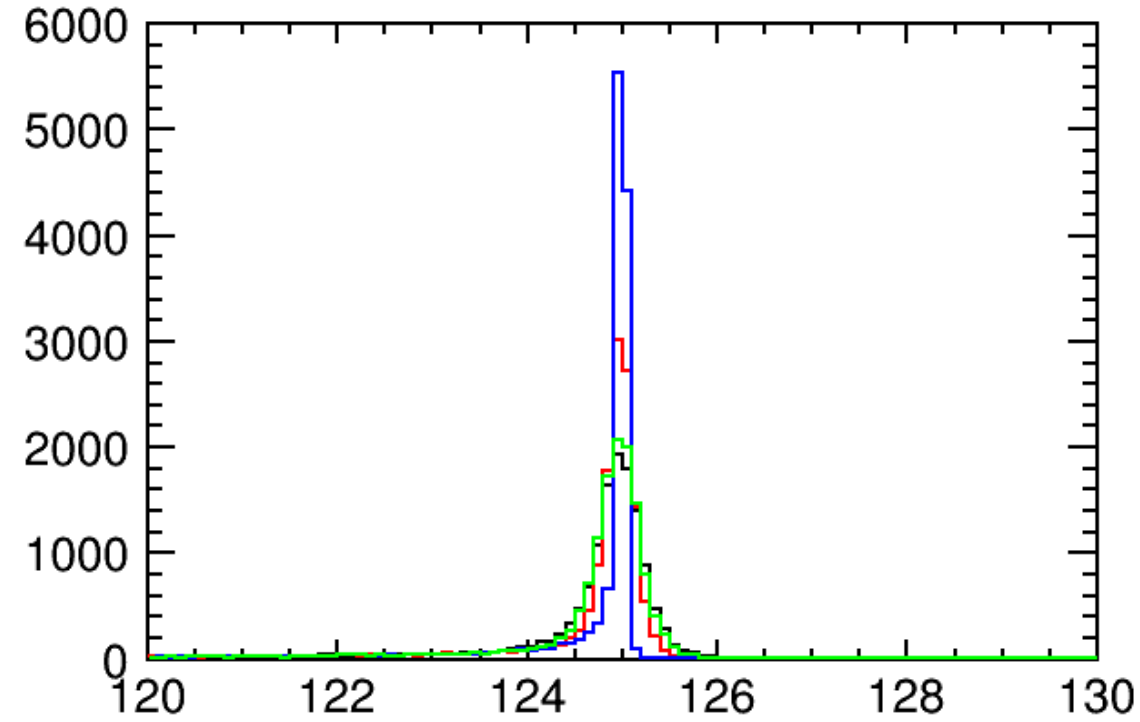
- Use these formula together with $\sigma_{p_T} = p_T^2 \times \sigma_{1/p_T}$.
- When we assume some number of σ_{1/p_T}, we have σ_{p_T} and can make smearing by changing $p_T \rightarrow p_T + \sigma_{p_T}$.
  - adding term: gRandom->Gaus(0, σ_{p_T})
  - p_T and angle parameters are obtained from MC truth
- Did not consider for smearing on angles
- Problem fixed in code. Re-processed all samples (straightforward, just need loooong CPU time for completion).

Intermediate Plots (before BDTG cut)

full
$1*10^{-5}$
$2*10^{-5}$
$3*10^{-5}$

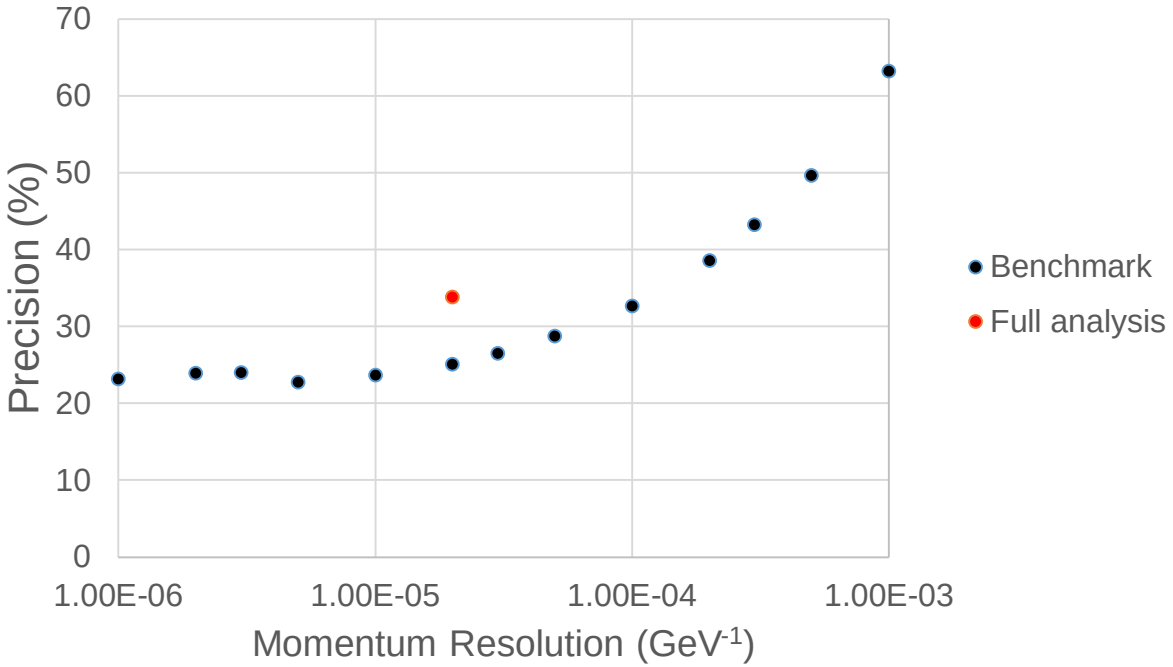


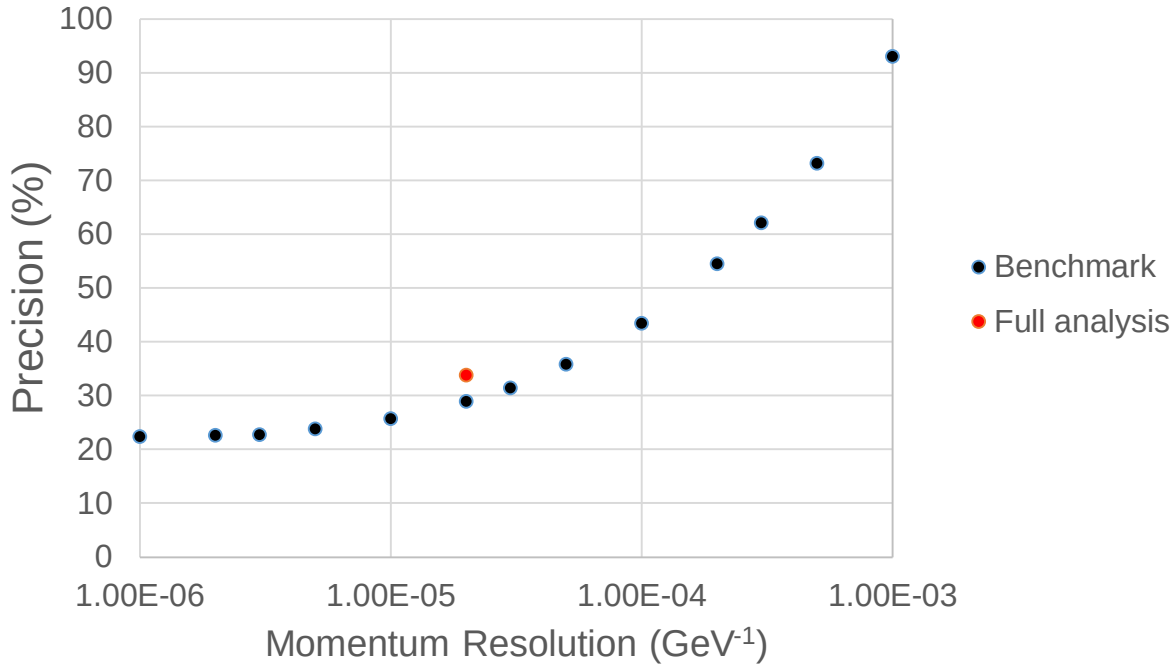
qqh250-L/R



nnh500-L/R

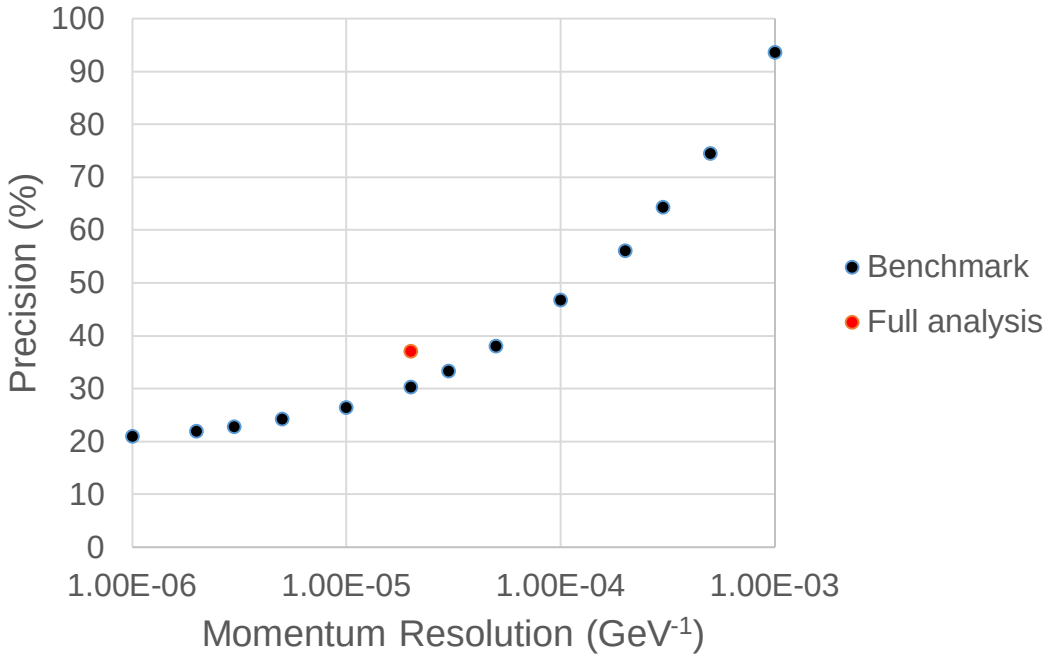
qqh250-L (previous vs now)

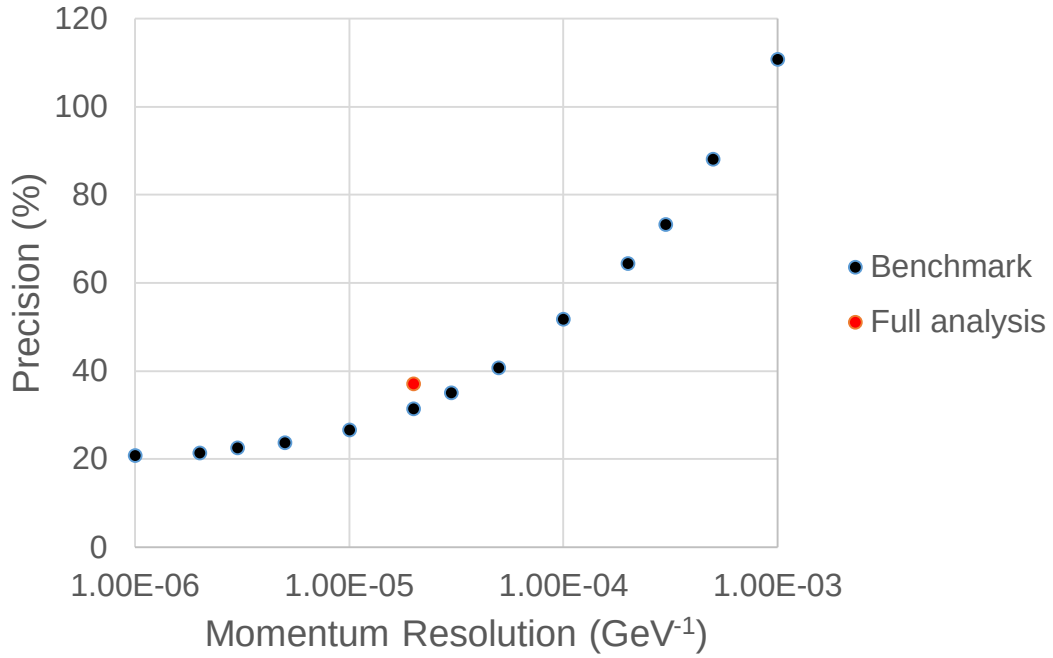




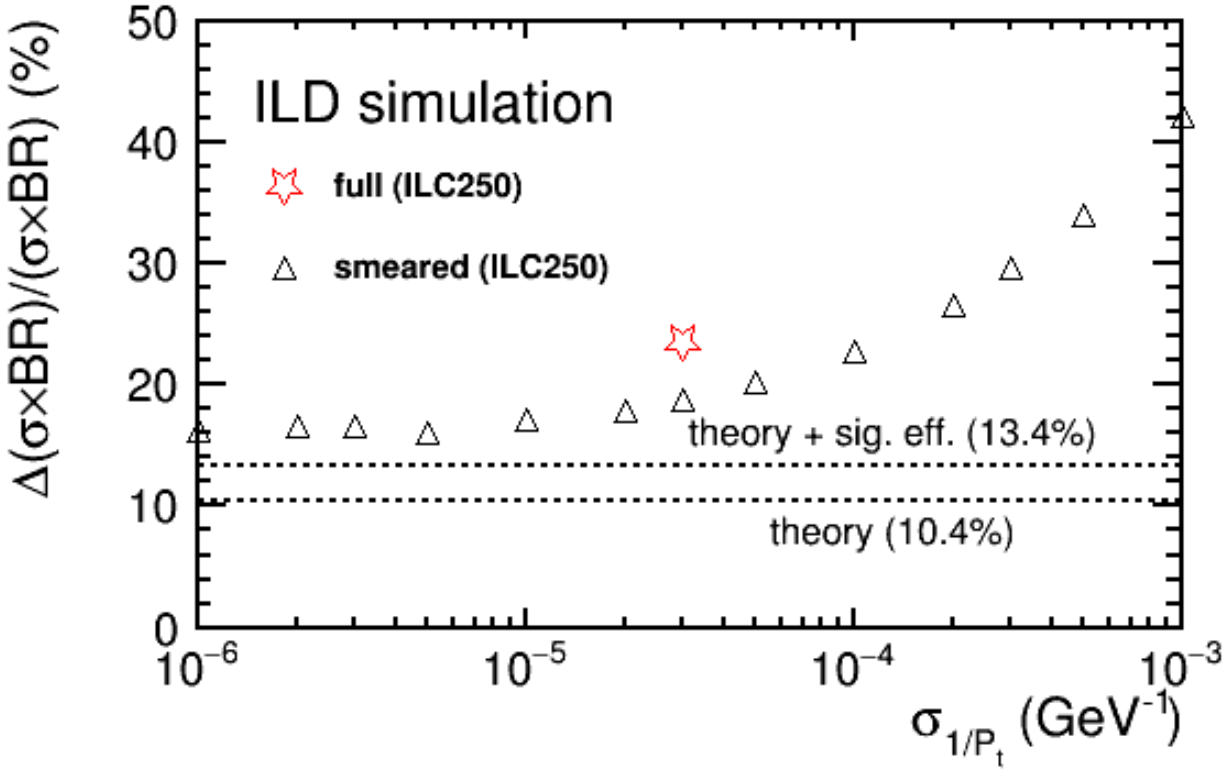
Why full result ~ $1*10^{-4}$ case in previous?
---> smearing was not accurate, made place of blue circles strange

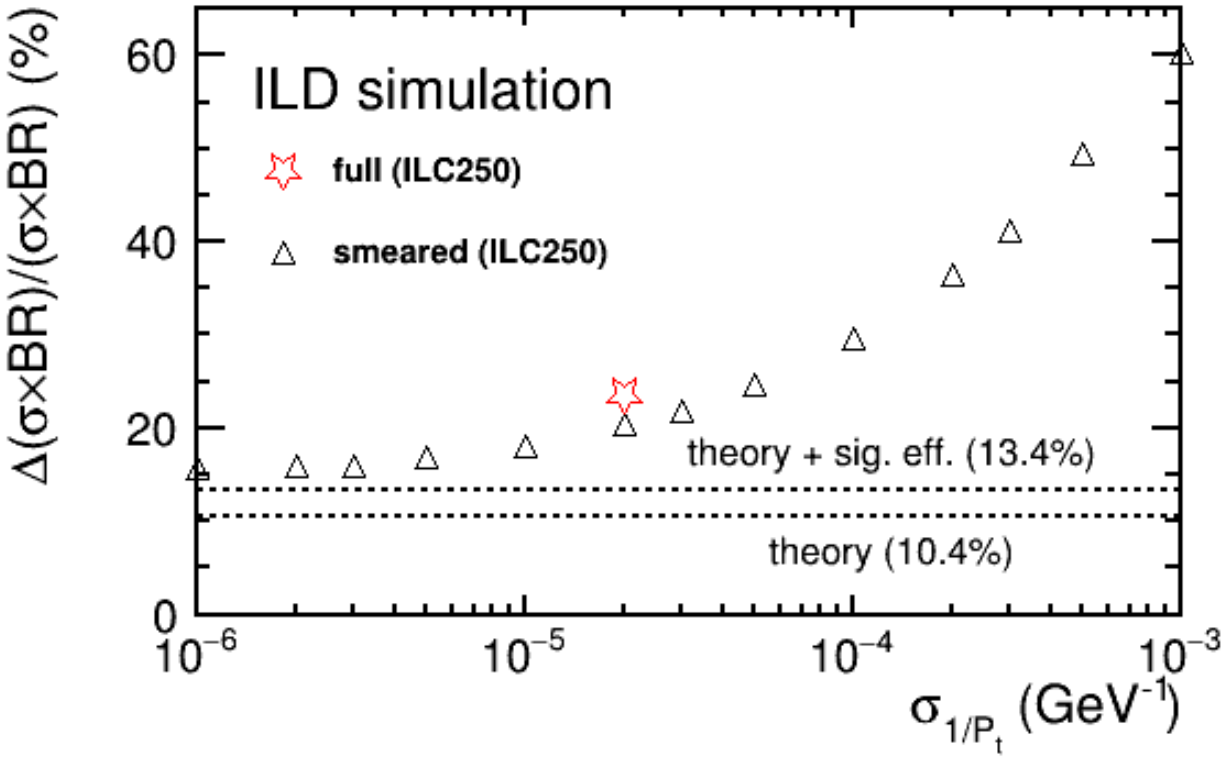
nnh500-L (previous vs now)





ILC250 (previous vs now)

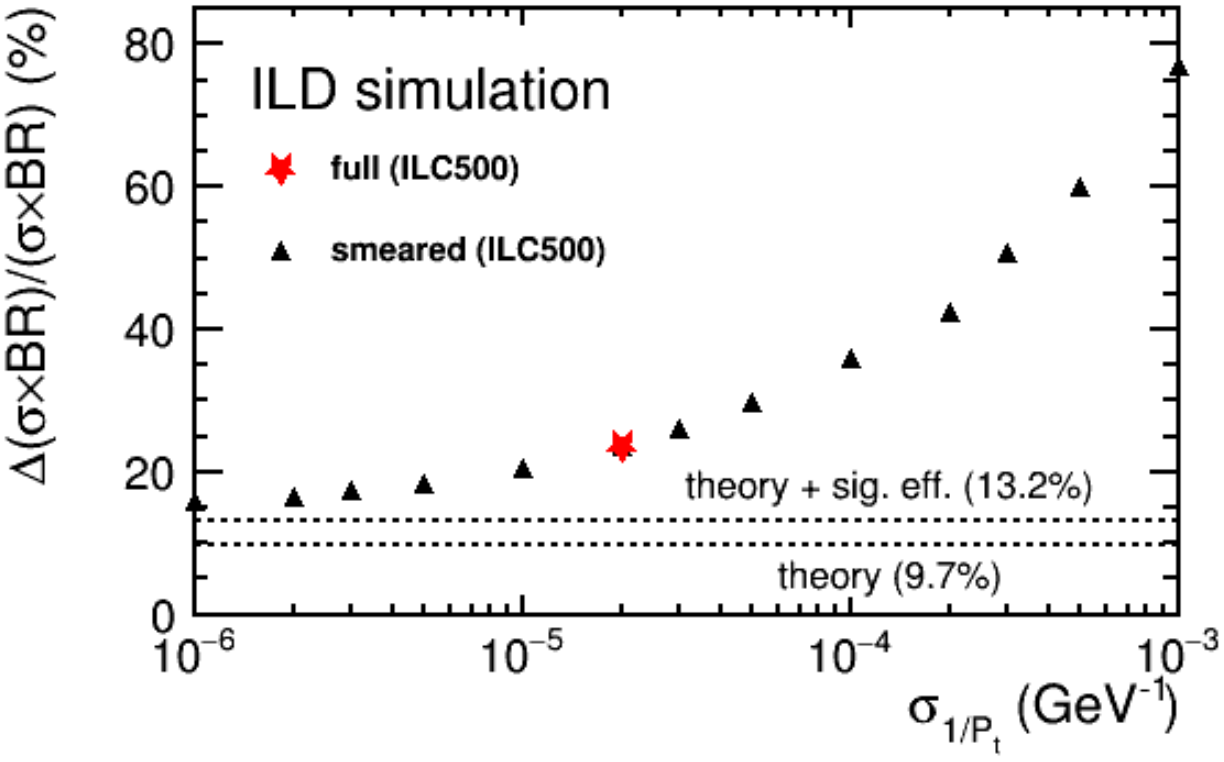


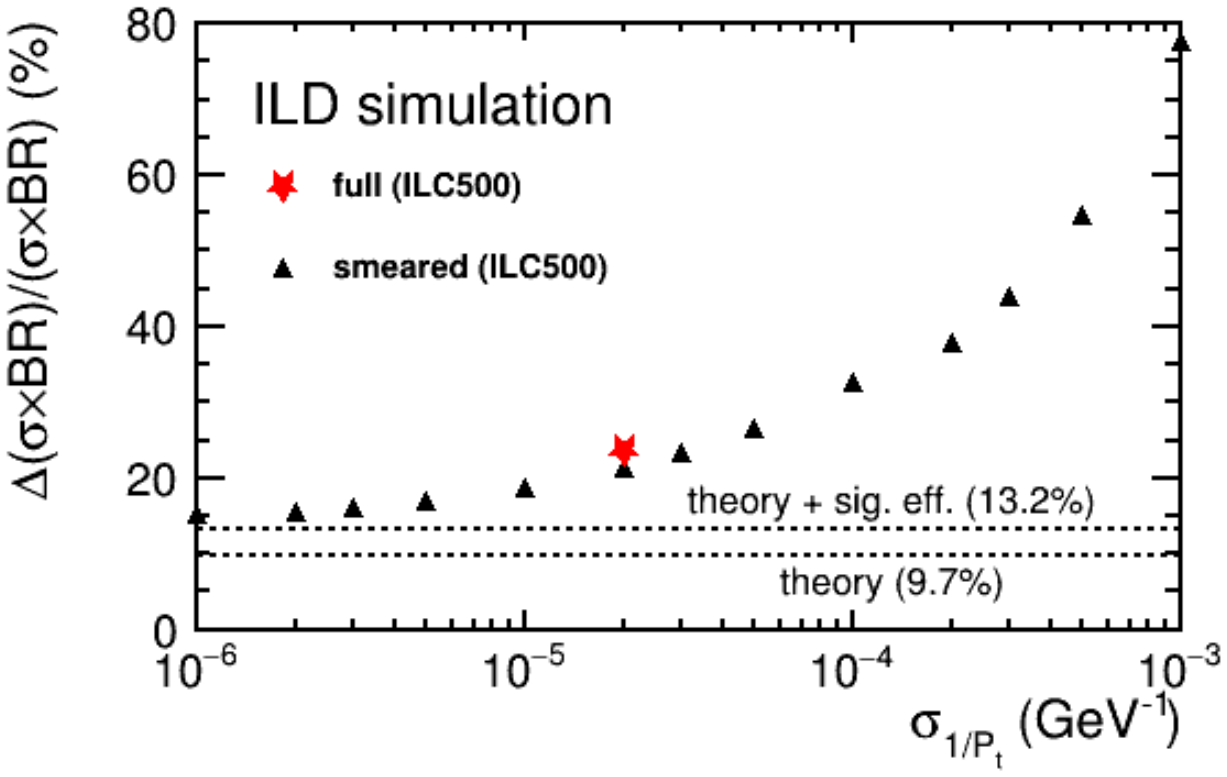


Why full result ~ $1*10^{-4}$ case in previous?

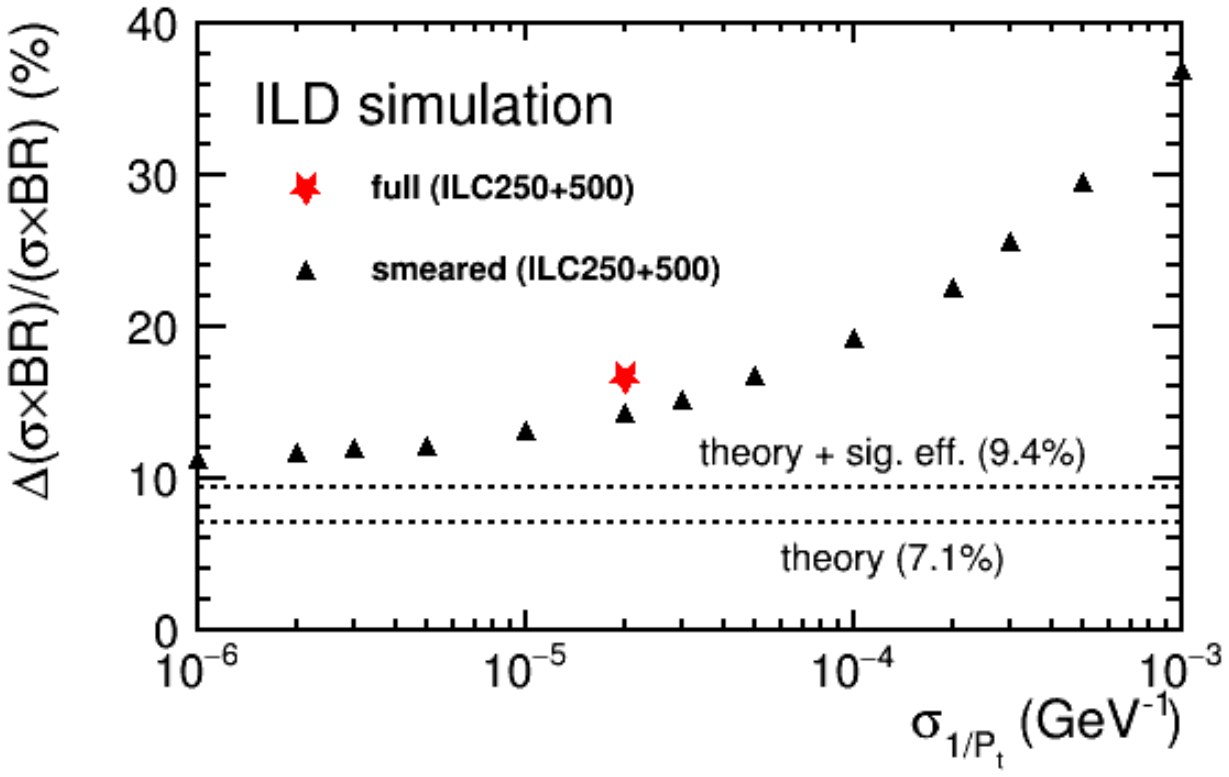
---> smearing was not accurate, made place of triangles strange

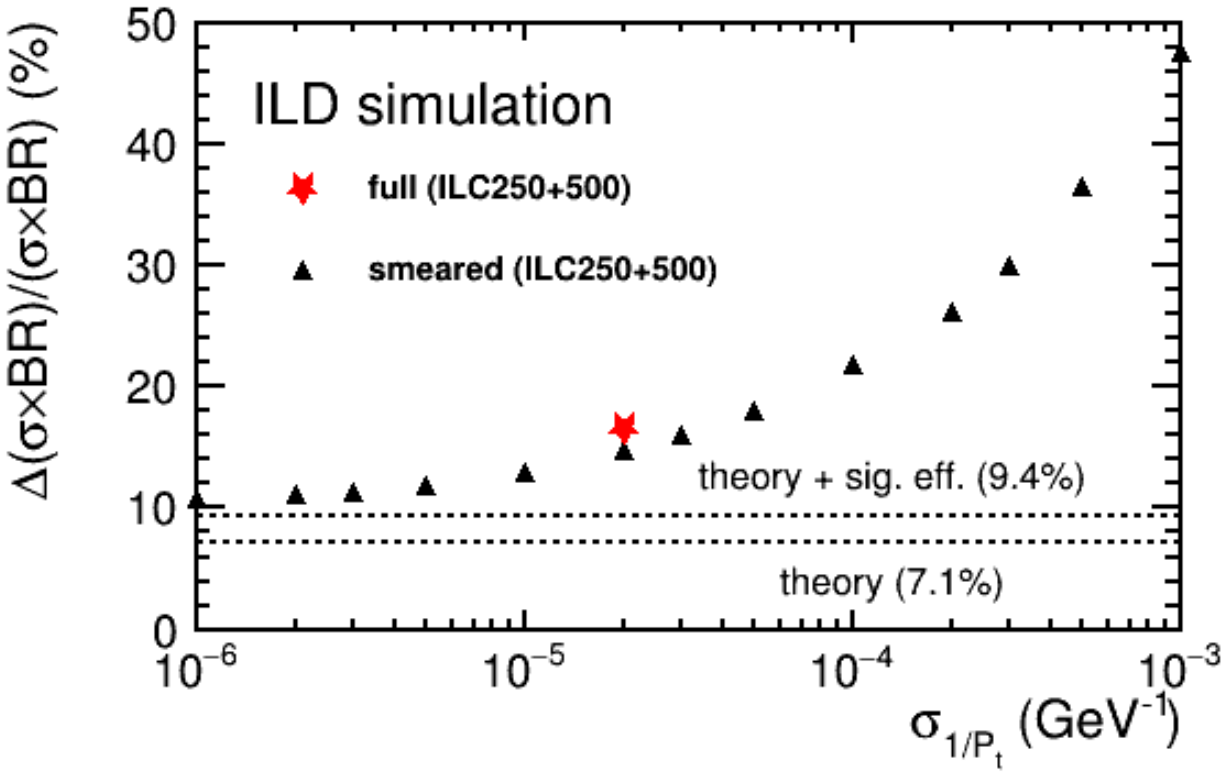
ILC500 (previous vs now)



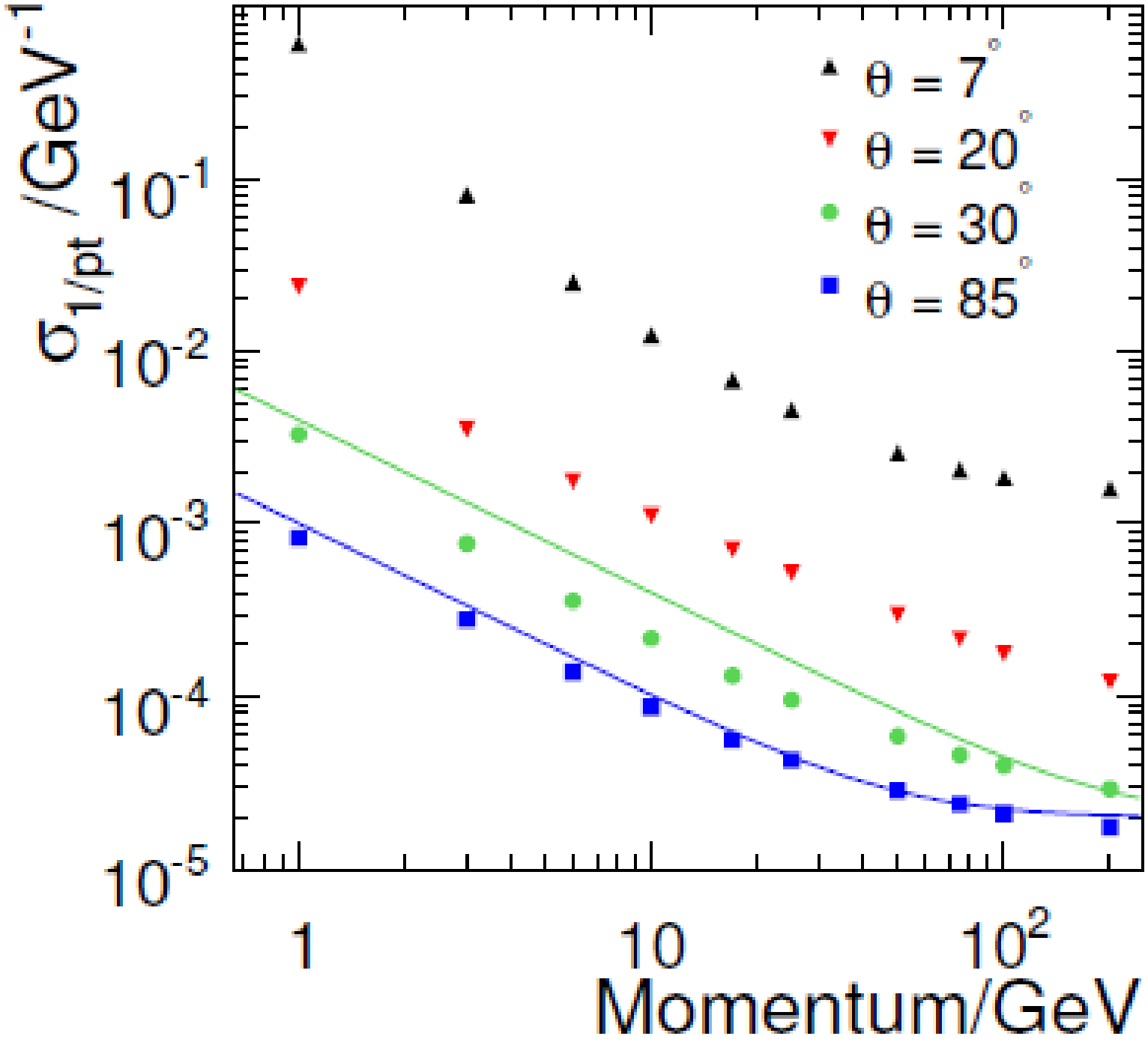


ILC250+500 (previous vs now)





from DBD


$\sigma_{1/pt}$ /GeV^{-1}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
1
10
10^2
Momentum/GeV
$\theta = 7^\circ$
$\theta = 20^\circ$
$\theta = 30^\circ$
$\theta = 85^\circ$

Summary

- Fixed problem in smearing, obtained plots with more healthy smearing.
- Rewrite paper of “Impact of the Transverse Momentum Resolution” section (and “Summary”).
  - All contents before this section (Introduction, The ILD Concept and MC Samples, Analysis) are finished including grammar correction.
  - Full draft circulation to reviewers would be March?

BACKUP

When we assume muons are massless, the invariant mass of muon pairs M can be written as;

$$M^2 = 2p_1p_2(1-\cos\alpha),$$

where p is momentum of muon and α is opening angle between two muons. The momentum p is equivalent to;

$$\begin{aligned}
p &= \frac{p_T}{\cos\lambda} \\
&= p_T\sqrt{1+\tan^2\lambda} \\
&= p_T\sqrt{1+\cot^2\theta} \\
&= p_T\sqrt{1+\frac{1}{\tan^2\theta}} \\
&= p_T\sqrt{\frac{\sin^2\theta}{\sin^2\theta}+\frac{\cos^2\theta}{\sin^2\theta}} \\
&= \frac{p_T}{\sin\theta}.
\end{aligned}$$

Therefore;

$$M^2 = 2\cdot\frac{p_{T1}p_{T2}}{\sin\theta_1\sin\theta_2}(1-\cos\alpha).$$

The $\cos\alpha$ can be re-written by using polar angle θ and azimuthal angle ϕ as;

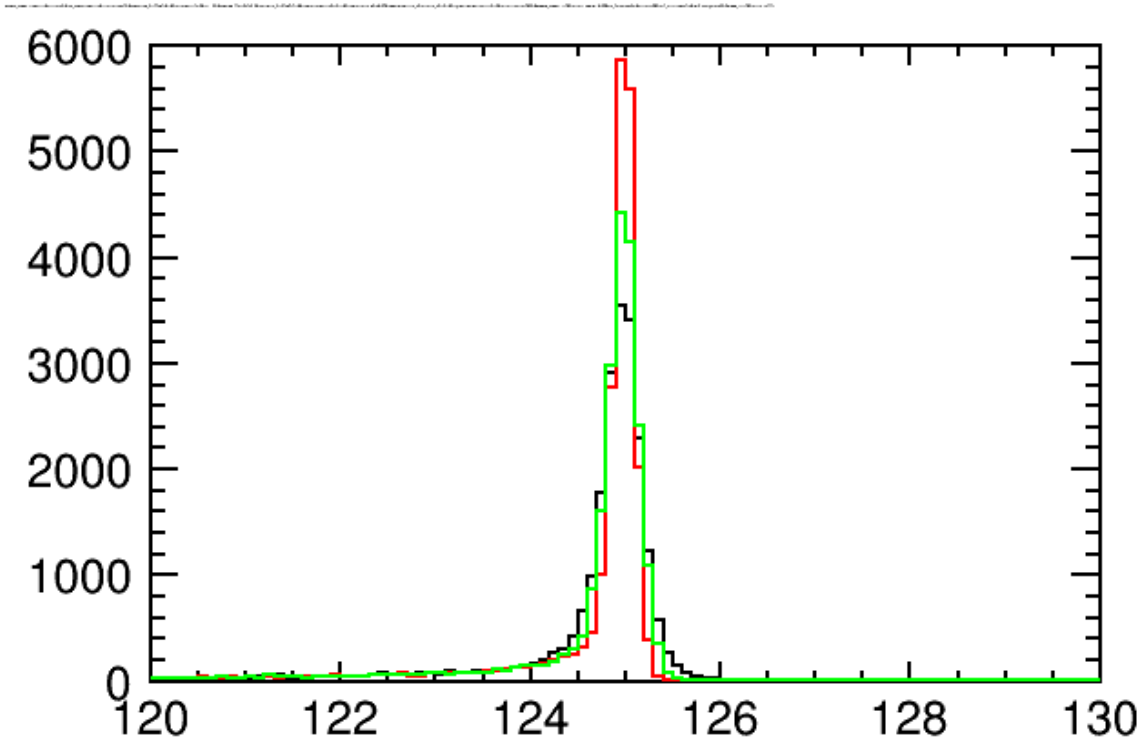
$$\begin{aligned}
\cos\alpha &= (\sin\theta_1\cos\phi_1, \sin\theta_1\sin\phi_1, \cos\theta_1)\cdot(\sin\theta_2\cos\phi_2, \sin\theta_2\sin\phi_2, \cos\theta_2) \\
&= \sin\theta_1\sin\theta_2(\cos\phi_1\cos\phi_2+\sin\phi_1\sin\phi_2)+\cos\theta_1\cos\theta_2.
\end{aligned}$$

Finally,

$$\begin{aligned}
M^2 &= 2p_{T1}p_{T2}\left(\frac{1}{\sin\theta_1\sin\theta_2}-\cos\phi_1\cos\phi_2-\sin\phi_1\sin\phi_2-\frac{1}{\tan\theta_1\tan\theta_2}\right) \\
&\equiv 2p_{T1}p_{T2}\cdot\text{coeff} \\
\therefore M &= \sqrt{2p_{T1}p_{T2}\cdot\text{coeff}}.
\end{aligned}$$

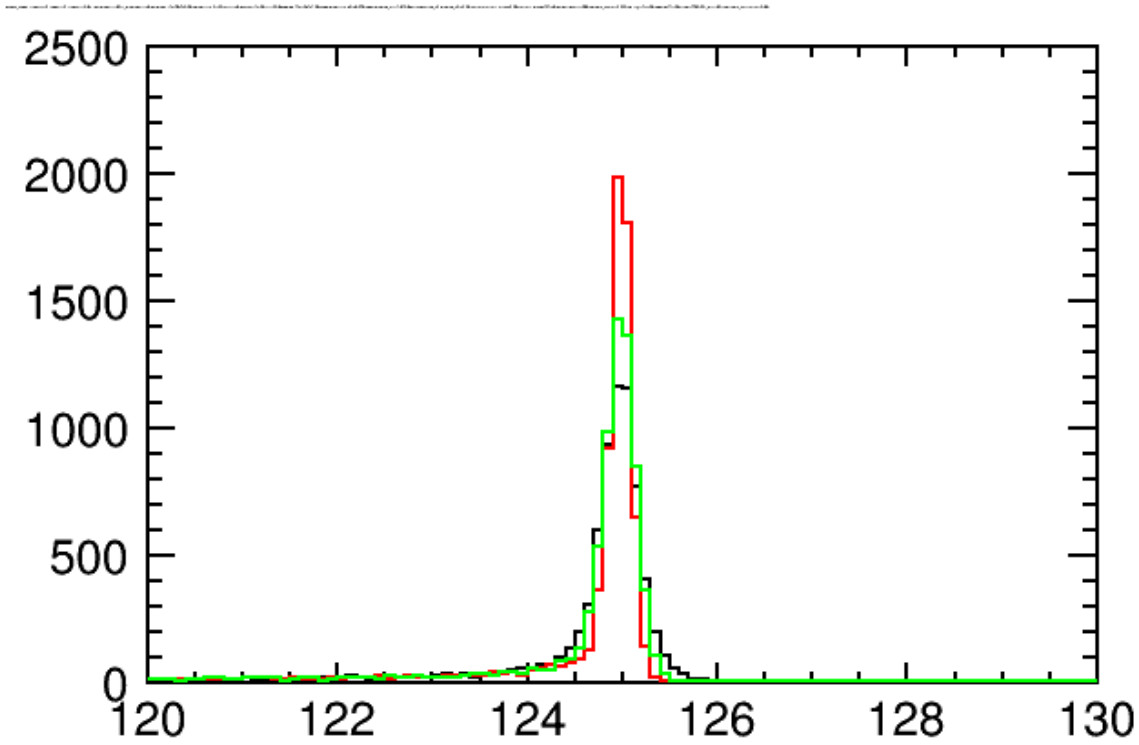
qqh250-L/R (before BDTG)

full
$1*10^{-5}$
$2*10^{-5}$
$3*10^{-5}$



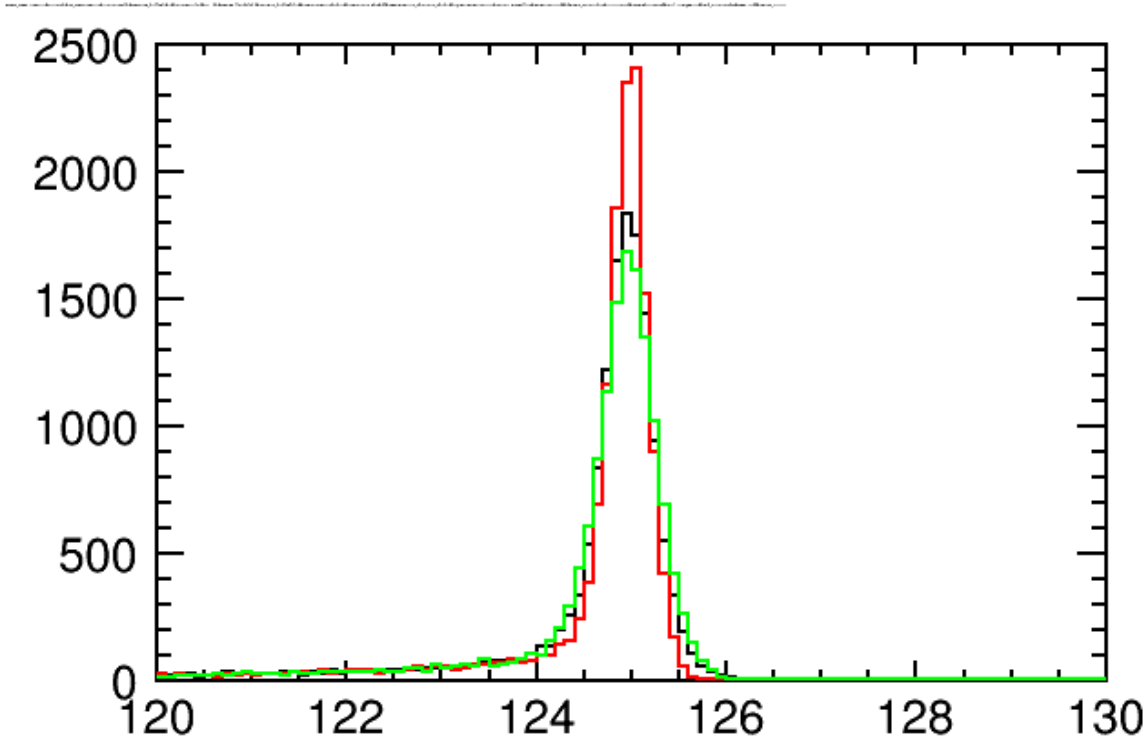
nnh250-L/R (before BDTG)

full
$1*10^{-5}$
$2*10^{-5}$
$3*10^{-5}$



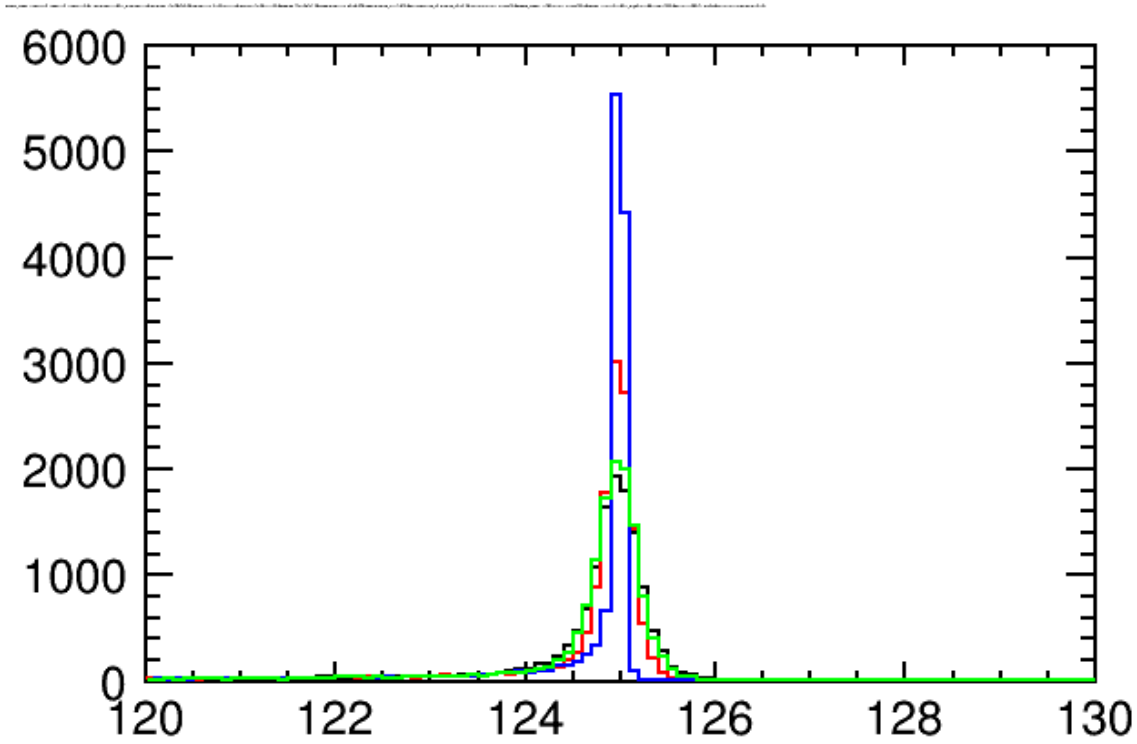
qqh500-L/R (before BDTG)

full
1*10^{-5}
2*10^{-5}
3*10^{-5}

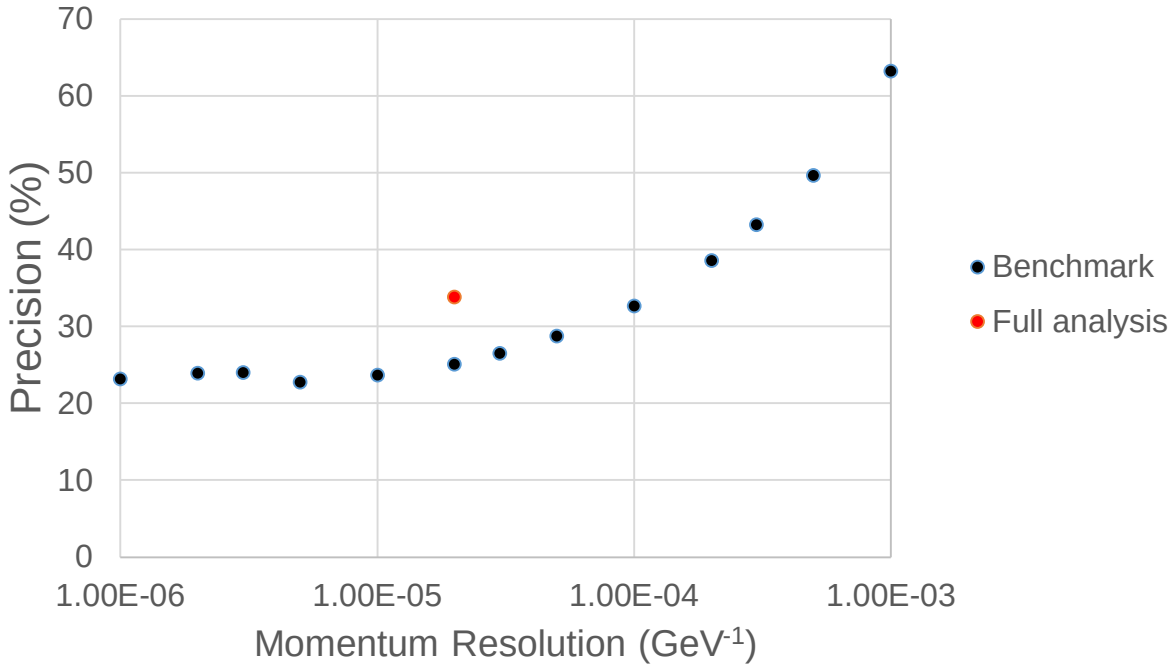


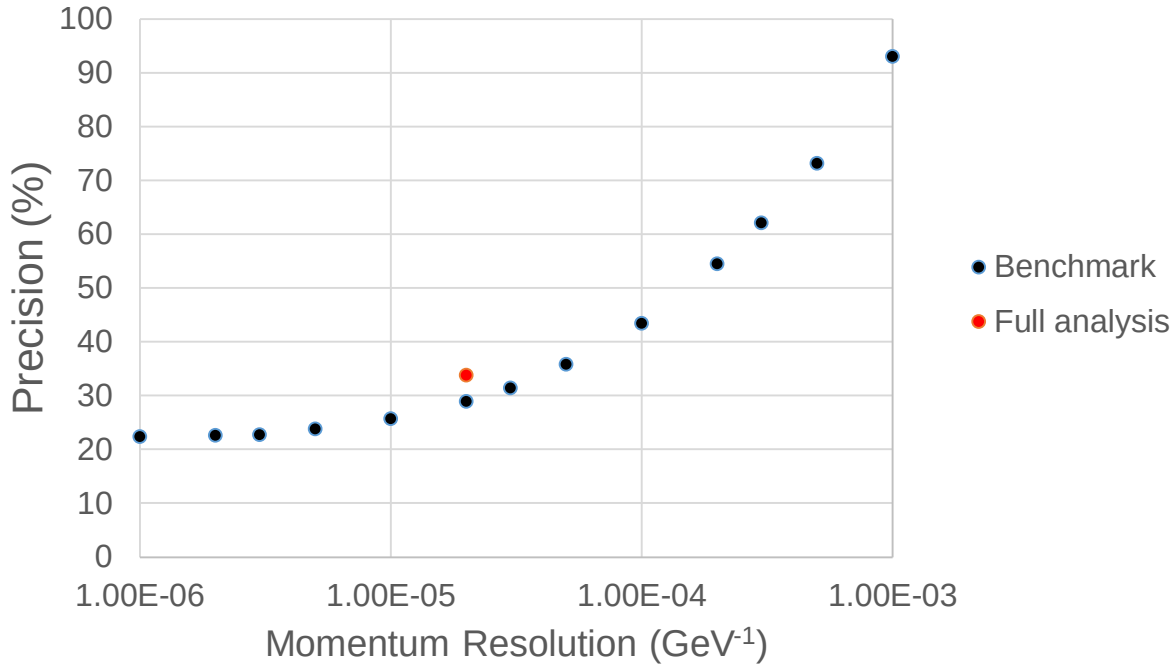
nnh500-L/R (before BDTG)

full
1*10^{-5}
2*10^{-5}
3*10^{-5}

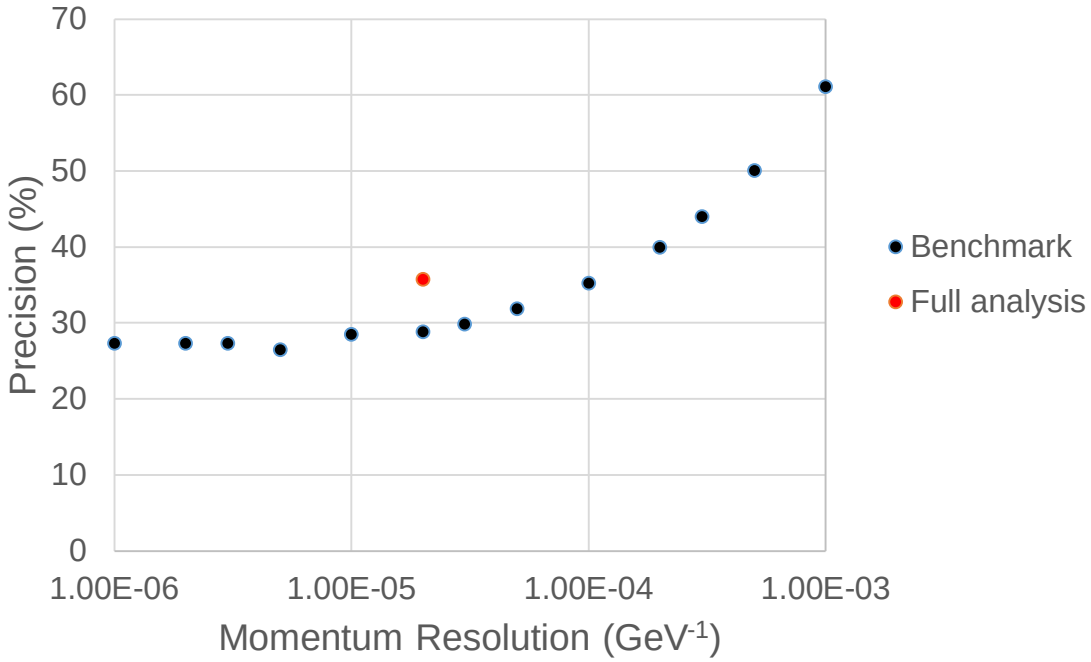


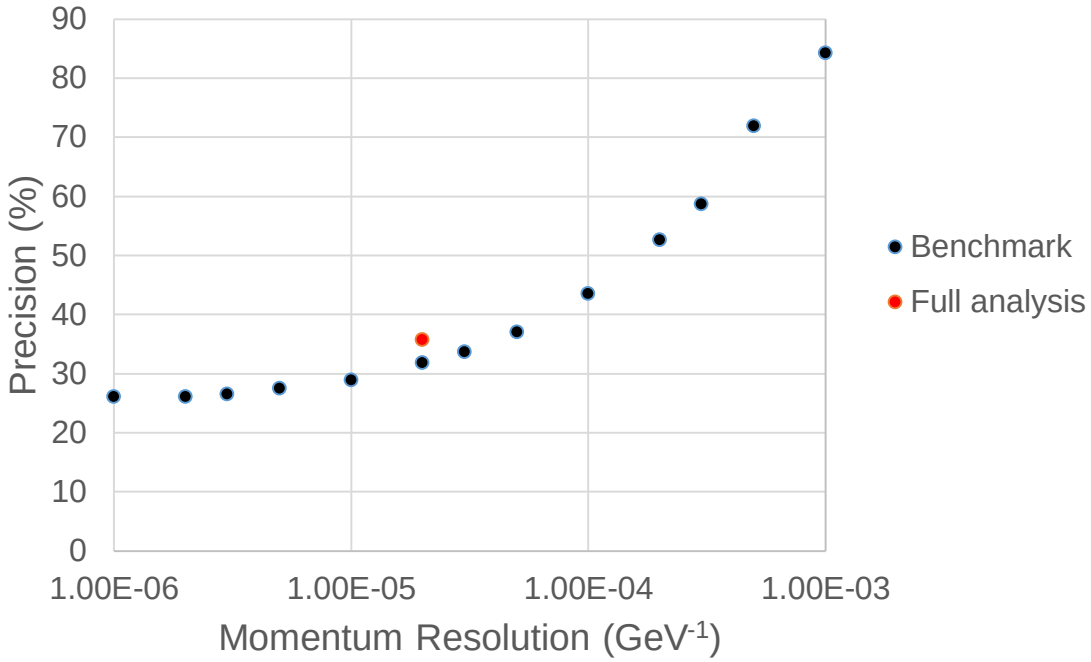
qqh250-L (previous vs now)





qqh250-R (previous vs now)





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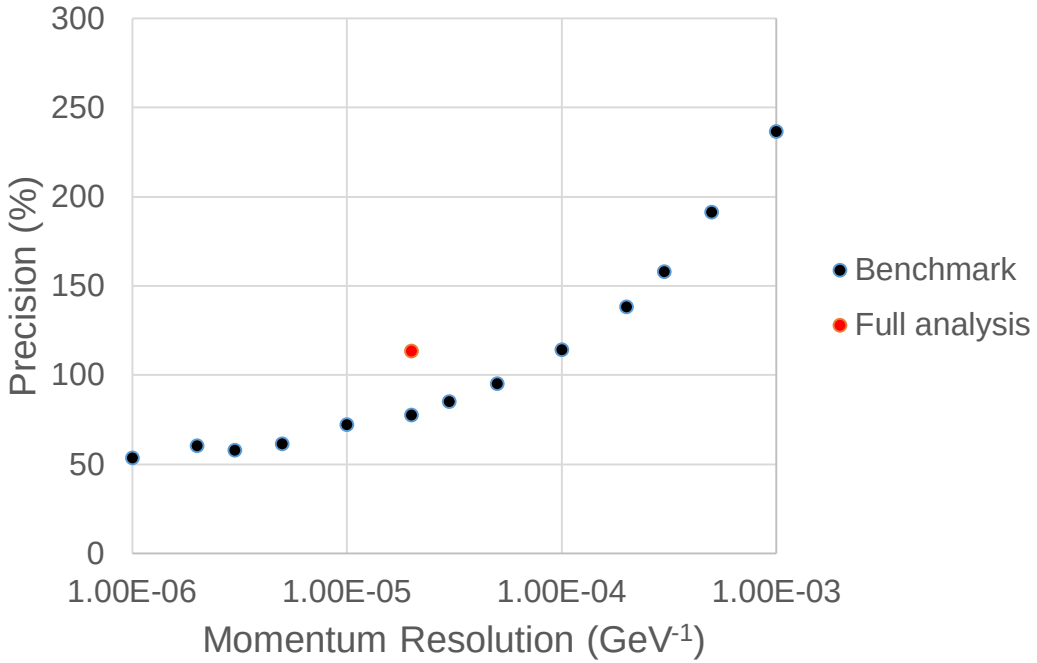

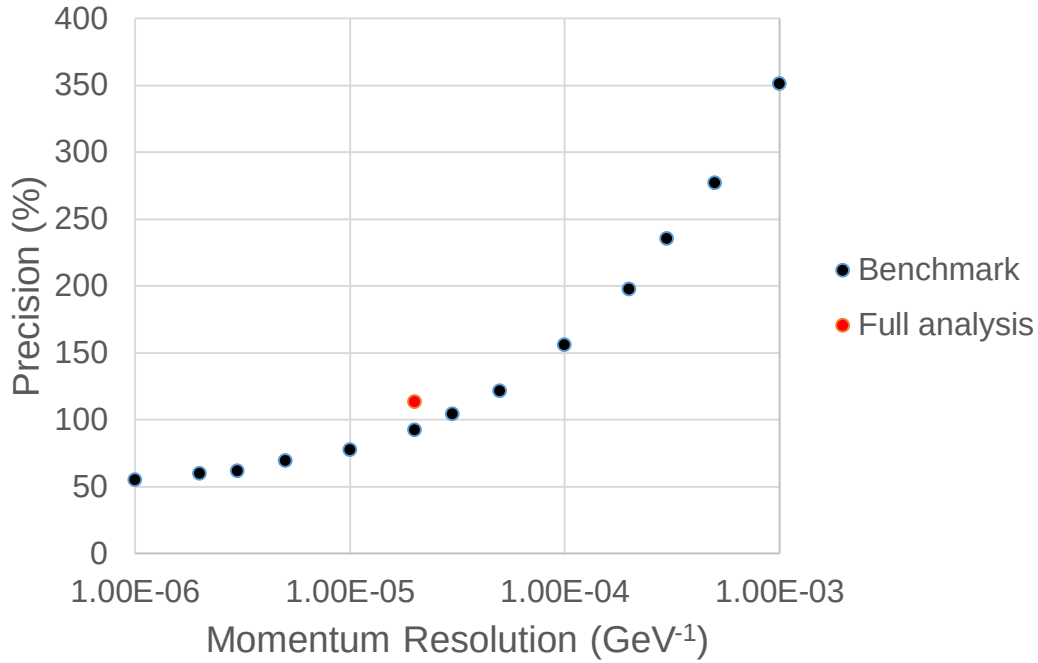

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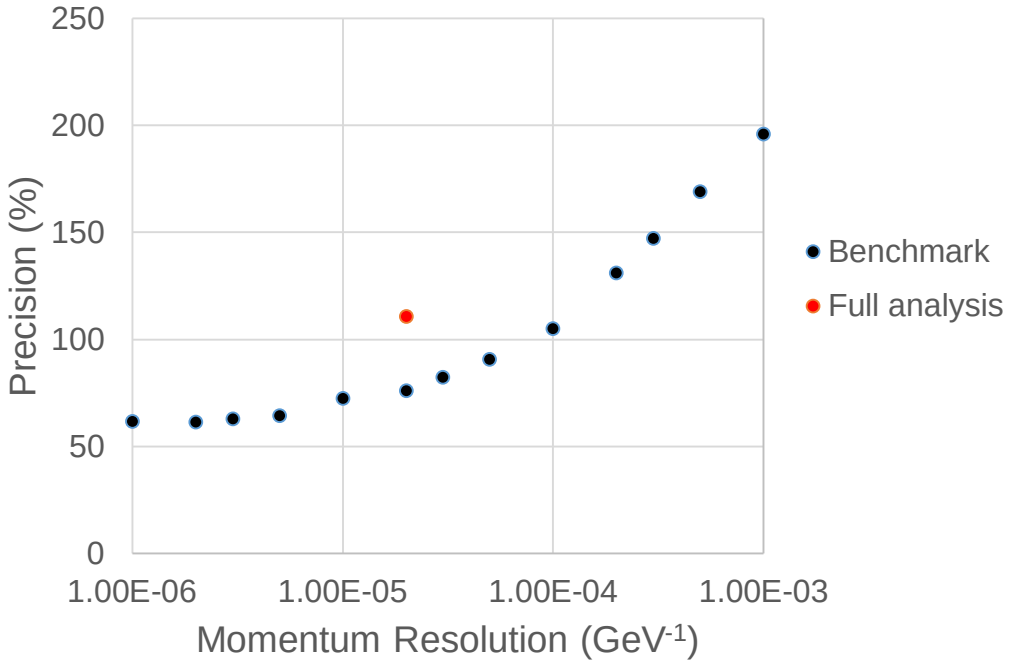
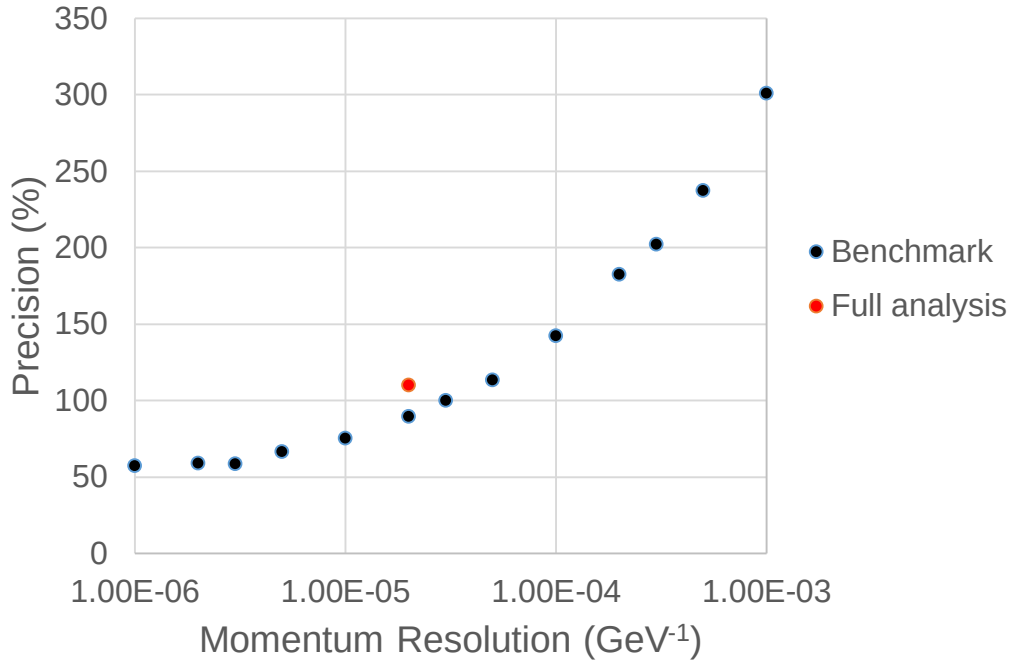
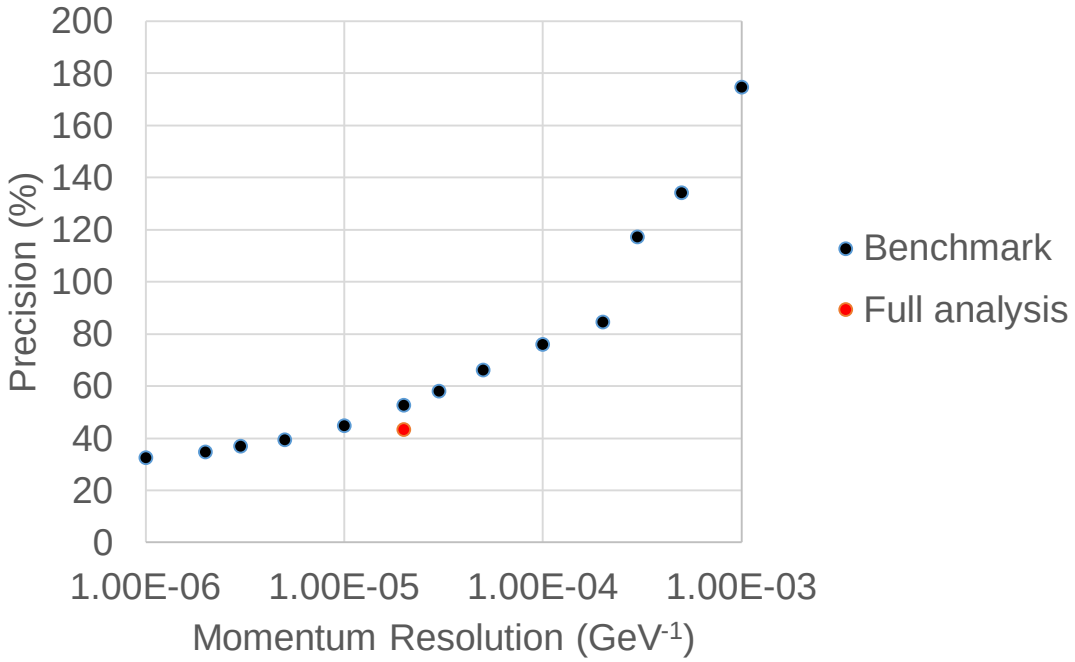
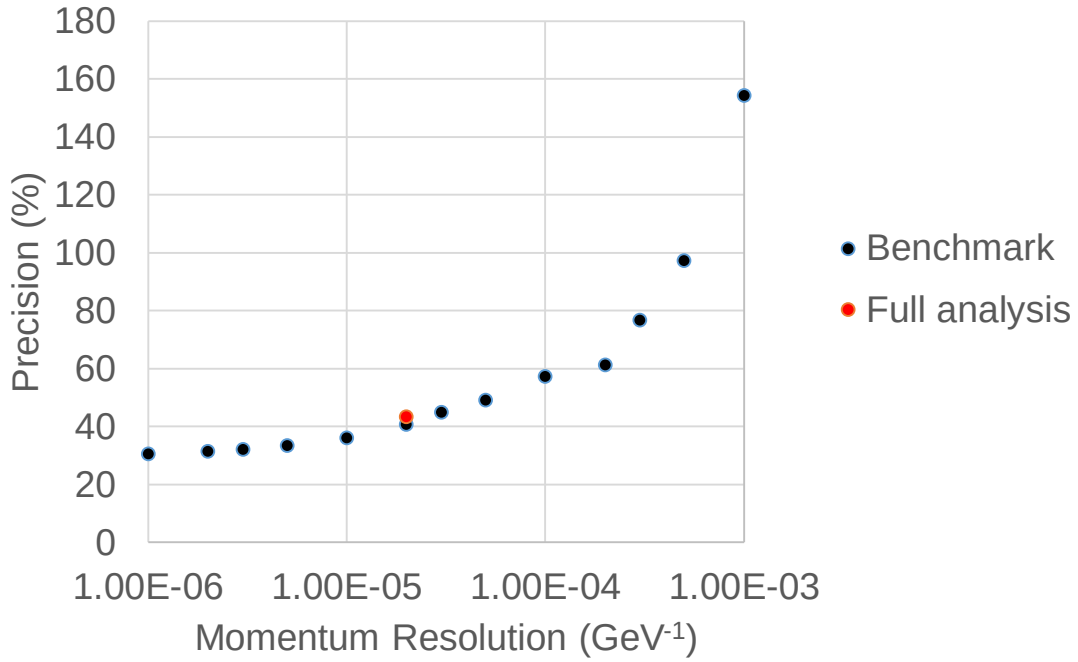




qqh500-L (previous vs now)





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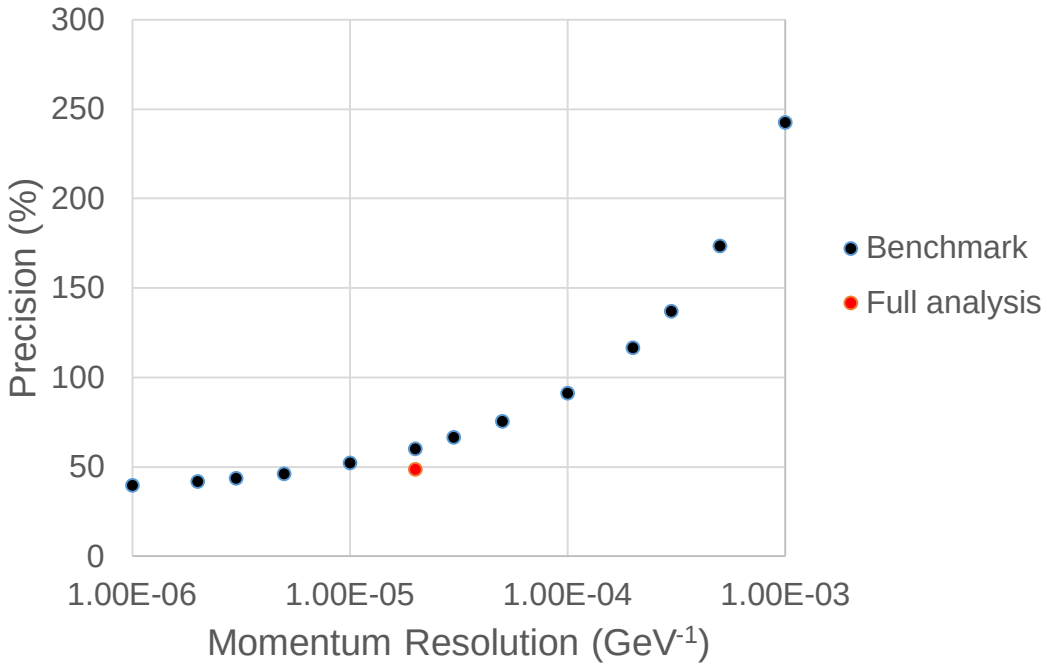

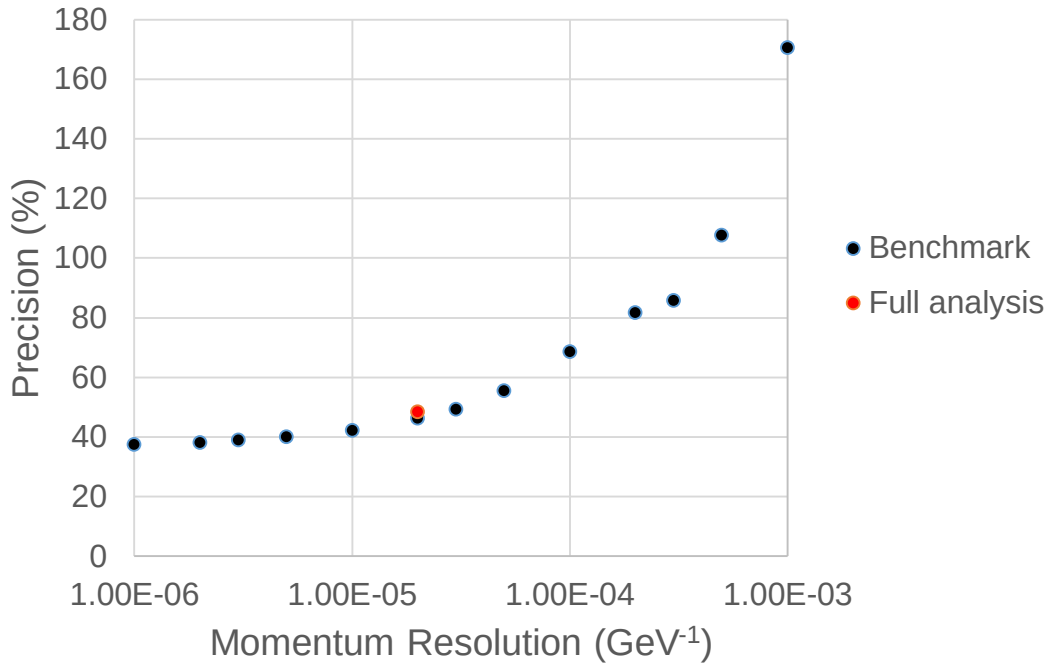

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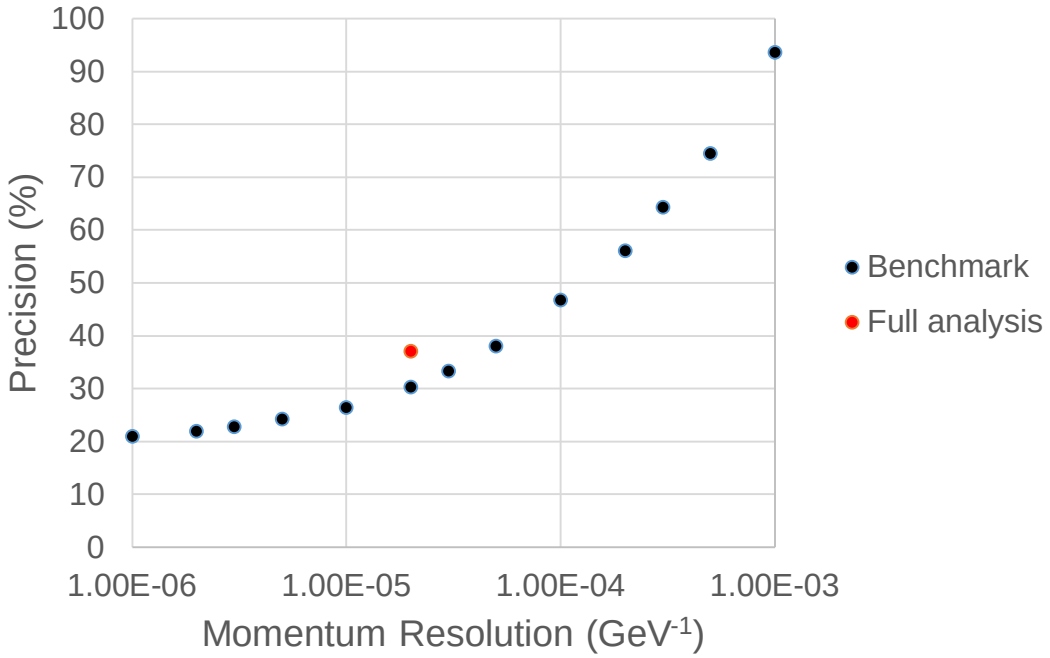

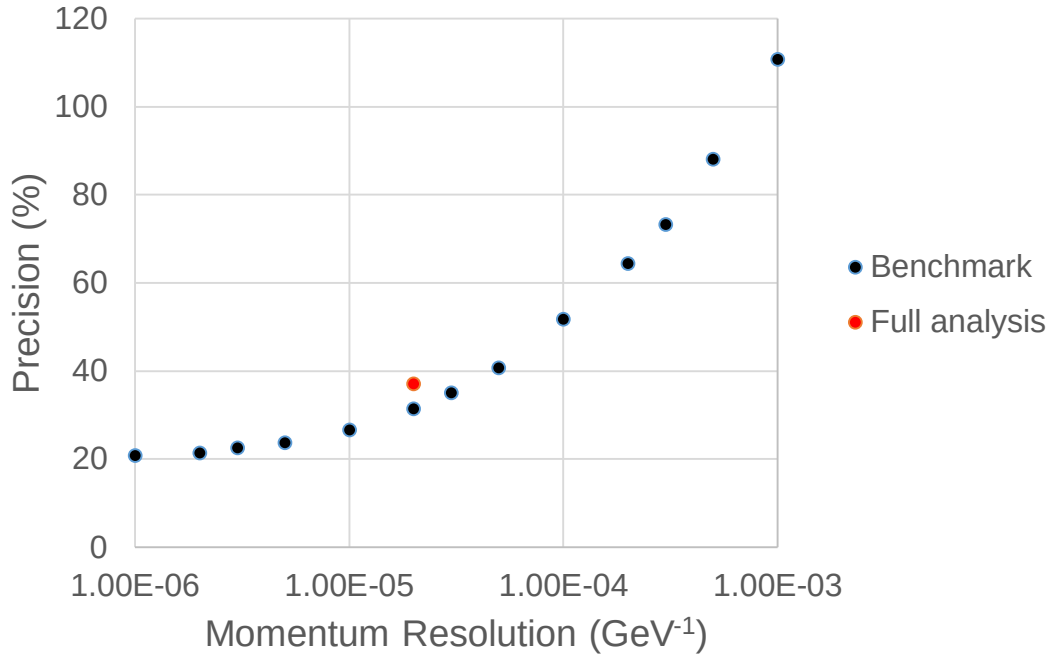

nnh500-R (previous vs now)